Near Shore Wave Processes

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LONG-TERM GOALS

Long-term goals are to predict the wave-induced three-dimensional velocity field and induced sediment transport over arbitrary bathymetry in the near shore given the offshore wave conditions.

OBJECTIVES

The interrelationship of wave-induced hydrodynamic and sediment processes over the vertical and morphologic processes at the bed are measured and modeled. The primary mechanism for changes in moment flux that drive near shore hydrodynamics is due to the dissipation by breaking waves, the processes of which are poorly understood. To improve our understanding of breaking waves, the dissipation associated with bubble injection is measured along with the velocity fields over the vertical. Bottom boundary layer measurements are obtained to determine bottom stress and dissipation. Sediment transport is measured in response to the measured mean longshore and cross-shore currents, wave velocities and induced stresses. The small-scale morphology, which acts as hydraulic roughness for the mean flows and perturbs the velocity-sediment fields, is measured as a function of time and over large areas to examine cross-shore and alongshore variation.

APPROACH

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A combined experiment (SteepBeach/RIPEX) investigating wave transformation over a steep beach (high Iribarren number) and rip currents was conducted April/May 2001 in Southern Monterey Bay as a pilot experiment to test instrumentation for NCEX. The large-scale morphology is a barred shoreline incised by deep rip channels spaced 100-200 m apart. Offshore of the bar the slope is 1:20, and the beach slope is steep at 1:5. An unexpectedly large variation in incident waves occurred during the experiment owing to a series of storms, resulting in waves up to 4 m at breaking. Comprehensive wave and current data were obtained for the first time on a steep beach and for rip currents, and these data greatly expand the range of measured beach processes. The experiment was a collaborative effort lead by Thornton and Stanton of the Naval Postgraduate School, PhD student MacMahan (University of Florida), and Lippmann (Ohio State University).

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14. ABSTRACT
Long-term goals are to predict the wave-induced three-dimensional velocity field and induced sediment transport over arbitrary bathymetry in the near shore given the offshore wave conditions.

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The comprehensive Delft3D morphodynamic model developed by Delft Hydraulics is being assessed by comparing with field data. This work is lead by Reniers (National Research Council post-doc) with participation of NPS graduate students. In addition, process models for breaking waves, momentum mixing due to the interaction of longshore and cross-shore vertical mean profiles, and bottom shear stress enhanced by the form drag of bedforms and by turbulence of wave breaking are compared with observations, which are the focus of Stanton, Thornton and their students. Both linear and nonlinear (Boussinesq) wave models (collaborative with Karakiewicz and PhD student Morichon, U. of Quebec) are considered.

WORK COMPLETED

Work completed includes and analysis of the SteepBeach/RIPEX data, improved techniques for determining reflection, and modeling the hydrodynamics and large-scale morphodynamics in the nearshore with an advanced Delft3D model.

1) The generation of infragravity waves by directionally spread short waves incident on an alongshore uniform beach was investigated using an advanced version of Delft3D. The infragravity wave response is examined using linear shallow water equations, taking into account the presence of bottom friction, set-up, rollers and the longshore current. The infragravity energy density spectrum and surface elevation at the infragravity band time scale is generated by summing all difference interaction frequency pairs of the input short-wave directional spectra obtained. Model results are compared with the data from the Delilah experiment (Reniers et.al., 2002a), and the results of the SteepBeach/RIPEX experiment (Reniers et.al., 2002b)

2) The breaking wave parameterization used in the Battjes and Janssen (1978) surf zone wave transformation model incorporated in Delft3D calibration was extended to include a larger range of field data including longer period swell (Morris et.al., 2002).

3) A new technique for determining wave reflection in the nearshore using PUV measurements as an extension of the work by Dixon et.al. (1995) was developed (Thornton et.al., 2002)

4) Data obtained during the SteepBeach/RIPEX was analyzed. Pulsations of the rip currents at infragravity frequencies were found to be the result of wave group forcing (MacMahan et.al., 2002).

5) Significant very low frequency energy (VLF's) with periods greater than 5 minutes outside the region of zero-mode edge waves was found and shown to be attributed to directionally broad wave group forcing and/or instabilities of the rip current itself, resulting in large-scale vorticies (MacMahan et. al., 2002).

6) The morphodynamics of rip current systems on an initially alongshore uniform barred beach with directionally broad spectral wave forcing with a mean angle of normal incidence is initially perturbed by VLF's and/or self organized motions that determine the alongshore length scale of the rip channels The rip channels are enhanced by a positive feedback of the wave group forcing and rip currents themselves. The alongshore scale of the rip channel spacing is shown to be a function of the directional bandwidth. (Reniers et.al., 2002c).

7) The Delft3D morphodrodynamic model was assessed by comparing model output with data from Duck94 experiment.

RESULTS

The morphodynamic response of an embayed beach induced by wave groups generated by a directionally broad wave spectrum with mean angle normally incident is examined with a numerical model (Reniers, et.al. 2002). The model utilizes the nonlinear shallow water equations to phase resolve the mean and infragravity motion in combination with an advection-diffusion equation for sediment transport. Starting with an initially alongshore uniform barred beach, the bathymetry evolves to the shoals cut by quasi-periodic rip channels. Without directional spreading, the smallest alongshore separation us obtained and the beach response is self-organizing in nature. Introducing directional spreading results in a limited range of preferred spacing between rip channels, qualitatively similar to observations (Figure 1). The hypothesized correlation between the observed rip spacing and wave group forced edge waves over the initially alongshore uniform bathymetry is not found. However, there is a correlation between the alongshore lengths of the wave-group induced quasi-steady flow circulations (very-low frequency oscillations) and the rip current spacing. This suggest that the scouring associated with the flow circulations of the initial wave groups triggers the development of rip channels via a positive feedback mechanism in which the small scour holes start attracting more and more discharge.

A linear version of the above model was used to generate infragravity energy density spectra and compared with data from the Delilah experiment. Two mechanism responsible for the generation of infragravity waves are considered: the release of the bound infragravity waves associated with changes in the spatial variation of the incident shore wave energy, and the forcing of trapped waves by obliquely incident directionally spread short waves. Typically, 80% of the infragravity wave height variability is explained by the model, of which 30% or less is due to bound infragravity waves (Reniers, et.al., 2002b).

Numerical model computations of infragravity motions are compared with measurements obtained during the RIP-current EXperiment (RIPEX) in concert with the Steep Beach Experiment (SBE). The experiments were performed at Sand City, Monterey Bay, CA, during the spring of 2001. The nearshore bathymetry was made up of shore-connected shoals incised by relatively narrow rip-channels spaced approximately 125 m apart. The comparison considers a 24 day period during which significant changes in both the offshore wave climate and nearshore bathymetry occurred. Analysis from the alongshore array (MacMahan et.al., 2002) indicates that there is significant energy in the cross-shore infragravity velocities, and that there is little alongshore spatial variation, even in the presence of rip channels. Rip current pulsations at the infragravity band frequencies were found linked to the infragravity motions of the bound and free long waves, as opposed to forcing by dynamic hydraulic head (wave set-up) associated with incoming short-wave groups with preferred drainage through the rip channels. Reniers et.al., (2002c) utilized a non-linear shallow water wave model operating on the time-scale of wave groups, to compare with measurements to examine the effects of the complex bathymetry on the infragravity motions (Figure 2). The temporal variation in infragravity conditions during the experiment is strong, with computational results typically explaining 75 % of the observed infragravity motions within the nearshore. In contrast to the temporal variation, the alongshore spatial variation in infragravity intensity during the experiment is generally small, even though the underlying bathymetry shows strong depth variations.

IMPACT/APPLICATIONS

On the basis of Delft3D hydrodynamic model comparisons with comprehensive nearshore field data acquired over two decades funded in all or part by ONR, it is recommended the U.S, Navy adopt Delft3D as an operational surf model.

TRANSITIONS

It is recommended on the basis of comparisons with comprehensive nearshore field data that the Delft3D hydrodynamics model be modified to include roller dynamics and then be adopted by the U.S, Navy as an operational surf model.

RELATED PROJECTS

1. Results of process modeling obtained on this project are being applied to nearshore modeling efforts under the following programs: Modeling Wave Dissipation within the Wave Boundary Layer (ONR), and Development and Verification of a Comprehensive Community Model for Physical Processes in the Nearshore (NOPP).

2. Collaborative modeling and data comparisons of breaking waves using Boussinesq equations is being performed by PhD students at the U of Quebec under co-direction with Barbara Boczar-Karakiewicz.

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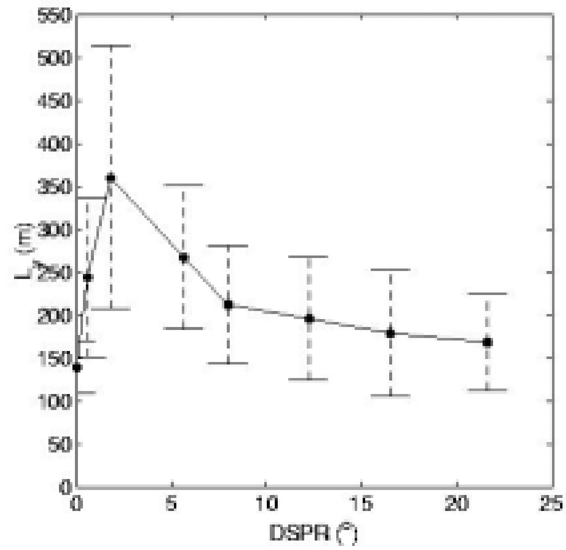

Figure 1. Model predicted average spacing between rip channels, L_y, for one-meter wave height with mean wave direction normal to shore varies between 150 m for unidirectional waves (zero directional spreading factor, DSPR) to 350 m for DSPR of 2^o and decreases thereafter for increasing DSPR, showing that the rip current spacing is bounded and in qualitative agreement with observations. The bars indicate the standard deviation of an ensemble of 8 simulations.

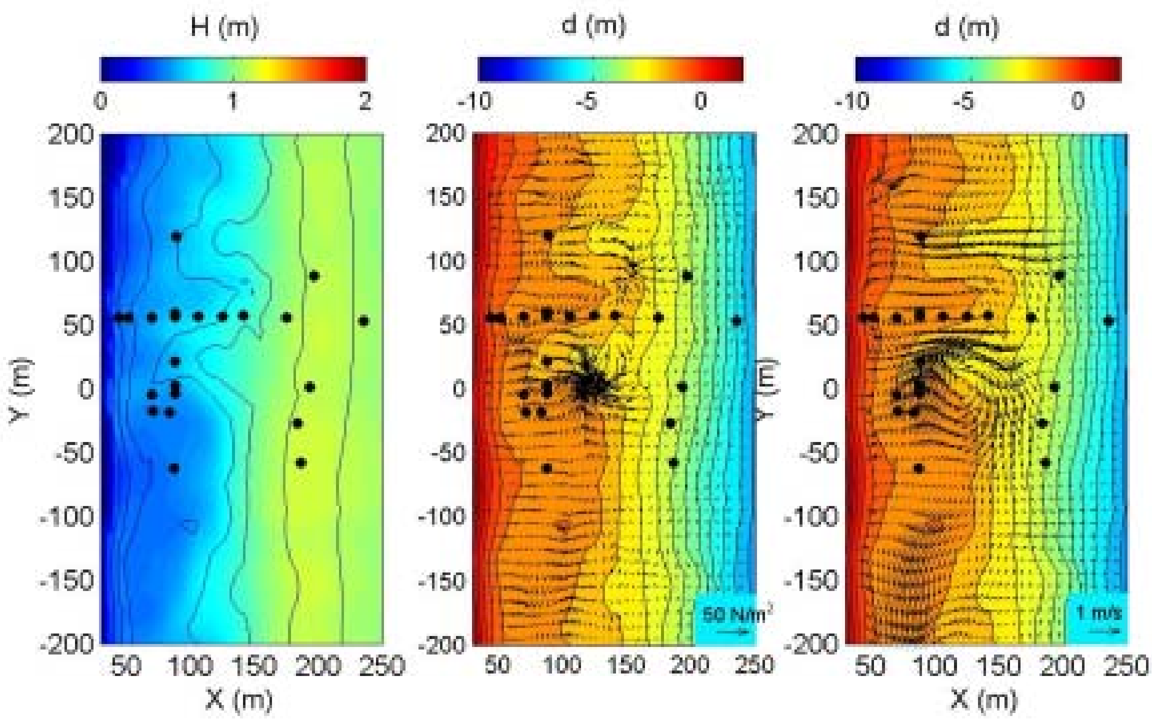

Figure 2. Predicted wave heights (left panel), radiation stress and pressure gradient forcing (middle panel) and currents (right panel) overlying bathymetry and denoting location of sensors during SteepBeach/Ripex experiment. A rip current at 120m alongshore and very low frequency oscillations at 20 m alongshore are evident. Good comparisons with data are obtained.

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